IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER Notices of Requirement to enable the construction, operation and maintenance of the City Rail Link

EVIDENCE OF DR JOHN HERBERT HEILIG
ON BEHALF OF MEDIAWORKS NZ LIMITED (IN RECEIVERSHIP)
AND TVWORKS LIMITED (IN RECEIVERSHIP)

INTRODUCTION

1. My name is Dr. John Herbert Heilig. I am the Principal of Heilig & Partners Pty Ltd., a consulting engineering company based in Brisbane Australia.

2. I hold the qualifications of Bachelor of Engineering (BE) Honours and a Doctor of Philosophy (PhD), both from the University of Queensland in Australia.

3. I have worked in the mining and civil industry for more than 25 years and have extensive domestic and international experience in the measurement, assessment and impact of vibration and regenerated noise from blasting and mechanical activities associated with civil construction projects. I have been associated extensively with vibration analysis and prediction at more than 500 sites throughout the world. I have also provided advice to large scale tunnelling projects in Australia and overseas continuously over the previous ten year period. I have recently provided advice to projects within New Zealand, including the current Waterview project.

4. I have advised MediaWorks NZ Limited (in Receivership) and TVWORKS Limited (in Receivership) (collectively "MediaWorks") on matters relating to vibration and regenerated noise from construction activities. MediaWorks have engaged me to review the proposed alignment and potential impacts of the City Rail Link project on the operation of their broadcast studios. In this evidence I will focus on vibration issues. Mark Simpson will address the implications of that vibration for regenerated noise. He will also address the likely levels of operational noise and regenerated noise within the MediaWorks premises.

5. I confirm that I have read the Code of Conduct for expert witnesses contained in the Environment Court Practice Note and that I agree to comply with it. I confirm that I have considered all the material facts that I am aware of that might alter or detract from the opinions I express. In particular, unless I state otherwise, this evidence is within my sphere of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

SCOPE OF EVIDENCE

6. My evidence addresses the following:

- A review of the project as presented in the report prepared by Marshall Day Acoustics (MDA) reports, including the associated appendices;

- An analysis of the expected vibration impacts of the project, including independent modelling based upon my experience and knowledge of vibration transmission from equipment necessary to develop large scale tunnelling projects;

- Comparison of these generated vibration levels with the criteria presented in MDA report, as well as other criteria that I have considered relevant;

- Review the statements of evidence prepared by Mr. Newns, Mr. Whitlock and Mr. Harrison.

IMPACTS

7. It is unavoidable that both the construction and operational phases of the project will induce some level of vibration and accompanying regenerated noise. The extent of these effects will depend upon the type of equipment utilised and its proximity to sensitive areas. The most significant effects will occur as a result of construction and I will address them first but the operation of the tunnel may also result in disruption to studio activity as a consequence of regenerated noise, particularly as time passes and the City Link rail and rolling stock begins to generate more vibration and therefore regenerated noise.

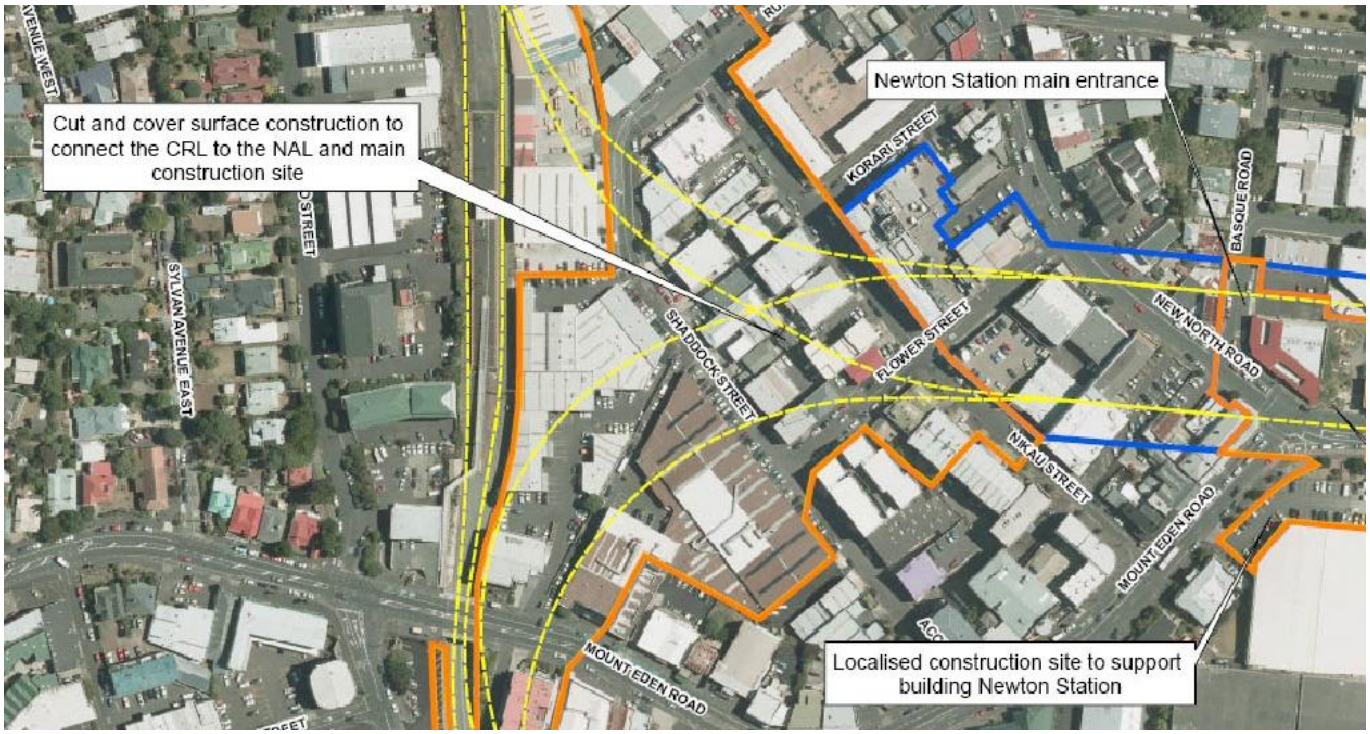
8. Vibration produces two types of adverse effect. The first is the damage, disruption or discomfort that arises directly from perception of the vibration itself. The second is regenerated noise which results from the vibration inducing very small momentary deflections in a surface, be that walls, floors and/or ceilings, where the pulse from these surfaces is emitted as an audible sound wave. The deflection need only be very small (commonly only tens of microns) to generate audible and often disturbing levels of noise. Depending upon the source and continuity of the vibration, the regenerated noise is heard as a low frequency hum or constant chatter.

9. Experience at other tunnelling projects has identified that audible regenerated noise occurs at very low levels of vibration, nearly always below the level at which the vibration itself is directly perceptible. Regenerated noise is the most significant environmental concern for construction activities undertaken near to residential or sensitive commercial properties. The effect is very pronounced for tunnelling projects where there is a shallow depth of cover between the crown of the tunnel and the basement of the building. It is generally noted that where vibration levels approach 0.1mm/s, some level of regenerated noise will be present and unfavourable impacts possible. The impact is exacerbated for some commercial properties, such as broadcast studios where both a quiet background environment is essential and the broadcast studio is a large, hard floor, expansive room.

10. The depth of the tunnelling activities beneath the broadcast studio in the south-west corner of the MediaWorks building is approximately 15 metres. The proximity of the bulk earthworks for the cut and cover component of the tunnel portal as well as its depth is unknown but is expected to be similar based upon the geometry and the requirement to link the tunnel with the existing NAL rail track. The method of excavation, and in particular whether drilling and blasting or mechanical excavation utilising a number of hydraulic hammers will be used has also not been fully established, however it is anticipated that a combination of those methods will be required in the area about the TV3 studio. This is consistent with the statement of evidence prepared by Mr. Newns.

LOCATION OF THE TUNNELLING ACTIVITIES

11. Drawings presented in the MDA reports show each of the tunnels broadening to accommodate double rail lines which allow connections to the up and down tracks of the existing North Auckland Rail Line. Drawings in the MDA report that show the vertical alignment of the tunnel indicate a distance between the crown and the surface of around 15 metres. The junction of the up and down tracks for the westernmost tunnel occurs almost directly beneath the eastern side of the MediaWorks building (below Flower Street). Whilst the main line tunnel north of this point towards the planned Newton Station could be excavated with a TBM, the section beneath the MediaWorks building is expected to require excavation using either a hydraulic hammer or road header. Importantly, with respect to the ability to operate a broadcast studio, either of these latter two construction methods produces slow rates of advance and will necessitate an extended period of construction beneath the building in comparison with a TBM, possibly with long periods of hammering or road header use very close to the main broadcast studio. The following drawing taken from the MDA report shows the alignment of the tunnel together with the junction with the turnout tunnel beneath the MediaWorks building.



12. In terms of vibration effects, a TBM is considered very efficient in excavating rock when compared to other methods, such as road header or hydraulic hammer. These other techniques are at least as disruptive in terms of generated vibration and much lengthier in duration. A TBM is therefore commonly preferable as a method of developing tunnels in populated areas. It is understood, however, through the discussions between Mr. Vaughan Smith and Auckland Transport representatives that construction with a TBM for the sections of the tunnels in the area about the MediaWorks building is not currently planned and the project will in any event need to utilise more intrusive methods of construction, such as a road header or hydraulic hammer, in the vicinity of the MediaWorks buildings.

13. As a guide, a TBM in full production could achieve advance rates of around 20 metres per day although values less than ¼ of this are expected during the initial start up period. Road header production rates depend upon rock mass strengths and the presence of defects, however production rates around 5 cubic metres per hour are a reasonable estimate. Based upon the estimated tunnel dimensions, vibration from the development of the second tunnel with a road header as measured at the MediaWorks site could persist for more than 1000

hours (ie; 40 days working 24 hours per day). Hydraulic hammering methods are slower again and may in unfavourable (i.e. competent) rock masses yield production no better than 2 cubic metres per hour, or more than 100 days (working 24 hours a day) for construction to the initial junction. Given the residential activities in the vicinity I suspect that 24 hour operation of those machines will be unlikely.

14. In my opinion, the requirement for two tunnels, the associated track junction of the westernmost line beneath the MediaWorks building and the consequential implications for tunnelling techniques exacerbate potential for incompatibility between the tunnelling operation and the MediaWorks activities. That incompatibility is likely to continue for at least several months.

LOCATION OF THE CUT AND COVER PORTAL WORKS

15. The extent of the portal works is not shown in the documents that I have been provided with, however the conceptual drawings indicate that the portal will be supplemented by approximately 100 metres of cut and cover works to ensure that the tunnel has a sufficient depth of competent rock above the tunnel crown and to allow connect at an appropriate grade to the existing North Auckland Line (NAL).

16. Ideally, the portal for any tunnel is positioned in a competent rock mass to ensure the stability of the opening. This same competency of the rock mass normally suggests that drilling and blasting will be required as a method of excavation. Removal of large quantities of competent material with a hydraulic hammer will be time consuming and against the normal tunnelling practise of accelerating works in the area of the portal to ensure that tunnelling can be commenced as quickly as possible.

17. The proximity of the MediaWorks buildings in the area of the portal, including the other residential properties along Nikau Street, will restrict the scale of any drilling and blasting activities. At best, blasting could be expected to accelerate the efficiency of the hydraulic hammering rather than eliminate the requirement for their use. It is most likely that a combination of drilling and blasting, as well as the extensive use of hydraulic hammers, will be required to construct the portal

area. This is consistent with the views of Mr. Newns where he indicates that the excavation will require the use of large excavators, typically around 100 tonnes.

ACCEPTABLE VIBRATION CRITERION

18. An appropriate vibration criterion will be one that ensures the vibration from the mechanical sources, described as continuous (eg: the TBM, vibratory rollers, and hydraulic hammer), or drilling and blasting activities, is maintained at levels below those that allow a broadcast studio and reporting facility to successfully operate. The MediaWorks building, and in particular any broadcast studios, must be differentiated from normal commercial buildings and a limit applied that permits these tasks to continue unimpeded. Imposing a permissible vibration level based solely on restricting damage to the building is inappropriate. The possibility of damage from low level continuous vibration is minimal but the disruption to a studio from such vibration can be significant.

19. An acceptable criterion for impulsive vibration, like that generated by blasting activities, must serve the dual purposes of ensuring persons within the building can continue to work normally, as well as ensuring it is incapable of affecting the potentially sensitive electronic equipment housed within the same building. The possibility of damage to the building, either superficial such as flaking of paint or cracking of plaster, or structural, is again very low and virtually impossible for limits that are normally applied to achieve the first two objectives.

20. Vibration limits are commonly assessed against values presented in standards or guidelines, such as the German Standard DIN4150. Projects in New Zealand commonly refer to the German Standard when defining appropriate vibration limits for blasting and this is consistent with the approach adopted in the MDA report. Human perception of vibration (ie. when one can sense vibration), as distinct from human comfort or amenity considerations, is summarised in German Standard DIN4150, Part 2-1975. The degrees of perception for humans for continuous vibration are given in the following table.

Approximate Vibration Level	*Degree of Perception*
0.10 mm/s	Not felt
0.15 mm/s	Threshold of perception
0.35 mm/s	Barely noticeable
1.0 mm/s	Noticeable
2.2 mm/s	Easily noticeable
6 mm/s	Strongly noticeable
14 mm/s	Very strongly noticeable

Table 1 – Summary of vibration effects

21. It is also commonly noted that at vibration levels approaching 1mm/s, small objects on hard surfaces may begin to rattle or move. Similarly, the surface of a glass water may also seen to be disturbed at vibration levels around 1mm/s. Whilst both of these effects would be of minimal consequence to most commercial properties, they are typically considered to be inappropriate for a television studio broadcast room. In addition to the levels of vibration that generate perceptible effects, significantly lower than these values (less than 0.1mm/s) however are noted to produce audible levels of regenerated noise.

PREDICTION OF VIBRATION LEVELS FROM POTENTIAL EQUIPMENT

Tunnelling with a TBM

22. In the absence of being able to undertake trials to establish the attenuation of vibration as a function of distance from the TBM cutter head specific for the City Rail Link project, best engineering practices consider other projects with similar characteristics in terms of the size of the equipment and the condition of the rock mass to best establish the possible effects.

23. To facilitate this, a relationship that represents the maximum vibration in any direction as a function of distance from the cutter head has been used developed from other projects and considered a relevant starting point for the assessment,

although some variation is expected from these predicted values. The relationship is shown in the graph below.

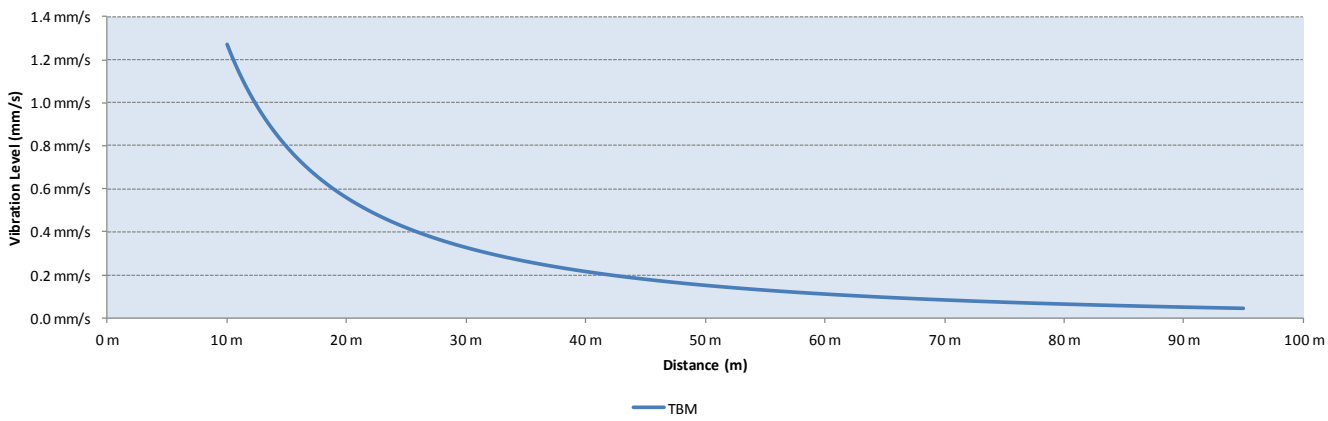


Figure 1 – Relationship between vibration level and distance for a TBM

24. In simplest terms, the modelled relationship suggests that vibration levels at a separation distance from the TBM of around 12 metres would result in vibration levels around 1mm/s (ie: 10 times the level that will cause regenerated noise). Compared with the information in Table 1, vibration of this magnitude would be classed as "Noticeable" and produce effects such as rattling of small objects on hard surfaces. The vibration would reduce to "barely perceptible" levels at a separation distance of around 30 metres and become "imperceptible" at approximately 50 metres from the cutter head. It should be noted that whilst the vibration may be imperceptible, the associated regenerated noise may exceed the necessary noise criterion for a broadcast studio. Mr. Simpson will discuss this effect further in his evidence.

Excavation with a Hydraulic Hammer

25. Whilst tunnel boring machines (TBM) are effective in developing long, relatively straight tunnels and are may be used to develop the section of the tunnels south of the MediaWorks building, other sections of these tunnels prior to where the tunnel junction exists will necessarily be developed with other methods, and most likely either using a hydraulic hammer or a road header.

26. To enable the prediction of vibration, vibration data have been also been analysed to allow the prediction of vibration levels at varying distances from a

hydraulic hammer. The modelling relationship has been adjusted to best reflect the level of vibration from the hammering activities with a hydraulic hammer mounted on a 30 tonne carrier. In all likelihood, should the tunnel be excavated with a hammer, either multiple excavators of this size would be required, or fewer larger excavators which would necessarily induce greater levels of vibration. The relationship between vibration level for a hydraulic hammer and distance are shown for both a small 30 tonne hydraulic breaker as well as a larger 85 tonne unit which I understand is more closely aligned with the proposed excavation equipment.

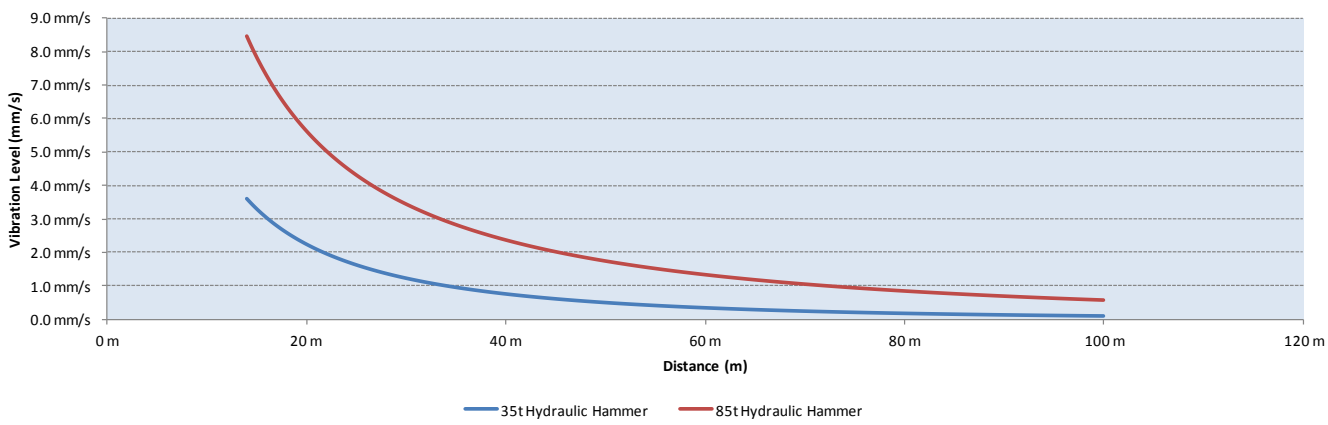


Figure 2 – Relationship between vibration level and distance for a hydraulic hammer

27. Based upon a separation distance for hammering activities from the tunnel and MediaWorks of 25 metres, a level of vibration range beyond 1.5mm/s could be expected from a relatively small excavator (ie: 15 times the level that will cause regenerated noise). The use of a larger hydraulic hammer attached to a larger excavator, such as an 85 tonne excavator, will necessarily introduce significantly higher levels of vibration, predicted to be in the vicinity of 4 to 5mm/s at a distance of 25 metres (Ie: 40 to 50 times the level that will cause regenerated noise).

Excavation with a Road Header

28. Like other equipment, a relationship between vibration level and distance has been sourced and used to estimate the vibration level from a road header. The results are shown in the following graph. The modelling results show vibration ranging between 0.4mm/s and 0.9mm/s, which would be considered “noticeable’

according to the effects in Table 1 could occur at distances between 15 and 25 metres.

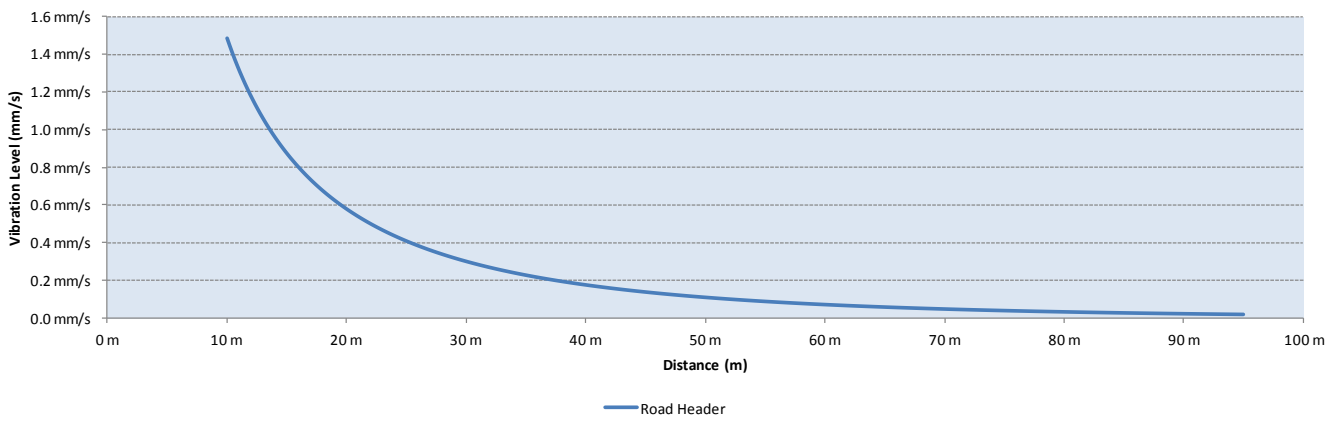


Figure 3 – Relationship between vibration level and distance for a road header

VIBRATION IMPACTS MODELLING

29. The expected impacts of the vibration and regenerated noise from three possible construction methods (TBM, hydraulic hammer and road header) have been analysed through a purpose designed vibration model specifically developed for assessing the environmental effects of tunnelling projects. The results for the modelling are given as a series of vibration contours for each of the equipment types that will be used in the different constructions areas. These drawings are attached to my evidence. I have considered only the westernmost tunnel however it should be noted that there will be a similar set of contours to the east in respect of the work to be carried out on the easternmost tunnel and a potential for elevated levels in between the two tunnel alignments if work on both tunnels occurs simultaneously.

30. In the simplest terms of analysis, where a vibration contour of say 0.5mm/s is shown, all areas between the tunnel and the area marked by this contour are predicted to receive vibration from the works exceeding 0.5mm/s (ie: five times the level that will cause regenerated noise). The modelling therefore identifies sections of the land around the tunnel where the vibration levels experienced as a result of the works exceed particular values. The modelling results identify clearly that construction will affect all areas of the MediaWorks building and will have a significant impact on the broadcast studio area.

31. The outcome of my modelling is discussed below:

32. Based upon the international standards, the level of regenerated noise for a broadcast studio should be kept below 25dBA which equates to vibration levels less than 0.06mm/s according to the FTA criterion for TV studios as provided in the MDA report.

33. The tunnel alignment necessitates that whilst part of the westernmost tunnel toward Newton Station could perhaps be completed with a TBM, the rest of that tunnel between the portal and the main track junction (>50 metres in length underneath the MediaWorks site) will require excavation with an alternative method, such as hydraulic hammer or a road header.

34. All tunnel construction methods for works beneath, and in the immediate vicinity of, the MediaWorks building are predicted to produce levels of vibration above the FTA requirements for necessary for a broadcast studio.

35. Alternative tunnelling methods that induce lower levels of vibration and regenerated noise are not options. The TBM method of construction for one of the tunnels produces the lowest impact in terms of vibration, and therefore regenerated noise, per tunnel metre of advance. These effects will however still exceed the vibration and regenerated noise limits appropriate for a broadcast studio. Excavation for the second track with either a hydraulic hammer or road header is modelled to produce higher vibration and regenerated noise levels that are unacceptable and above the requirements for a broadcast studio. Modelling predicts the TBM will generate vibration levels in the main broadcast studio up to 0.35mm/s which is well above the FTA permissible value. Higher levels are expected from the hydraulic hammer if this method is used to develop the second of the two initial sections of the tunnel. A small hydraulic hammer (mounted on a 30 tonne carrier) is predicted to induce around 1mm/s in the main studio whilst a larger 100 tonne unit is expected to induce vibration in the vicinity of 4 to 5mm/s at the same location. The road header is predicted to generate around 0.4mm/s. The productivity from either the hydraulic

hammer or road hammer will be significantly less than that achievable with the TBM.

36. Drilling and blasting activities have not been analysed in detail as the footprint of the portal area has not been defined in the project documents. Based on other similar projects, it is expected to involve works that cover an area of not less than 1000m^2. Vibration from blasting activities are proposed to comply with the German DIN 4150 standards which will ensure the integrity of the buildings around the portal are unaffected by the blasting. No analyses have however been provided in the MDA reports to confirm that all of the electronic equipment, including the audio and visual recording, within the TV3 buildings will not be affected by vibration. Electronic equipment has a lower permissible limit of vibration than for protection of buildings. The permissible vibration criterion is generally specified by the equipment manufacturer. Failure to comply with these levels could result in momentary failure, tripping or possible hardware damage.

37. If applied, the DIN4150 permissible level of vibration from blasting activities will allow for vibration which is clearly perceptible to persons within the building. Aside from its perception, rattling of small objects on hard surfaces would also be expected. Although the duration of any blast will be short and unlikely to exceed several seconds, it would be totally unacceptable to initiate a blast during any period when broadcasts were scheduled. Whilst it may be possible to initiate the blast at a time outside of these broadcast windows could occur, I note however there has been no assessment of the possible impact of vibration on the potentially sensitive electronic equipment within the MediaWorks building. I therefore conclude that until this is completed and demonstrated that it can be safely undertaken with respect to the continued operation of the equipment, blasting should not occur.

38. In summary:

a) The minimum extent of rock between the crown of the tunnel and the concrete floor of the broadcast studio results in elevated levels of vibration and therefore regenerated noise. Whilst the TBM is perhaps the most effective method of developing the tunnel and induces the lowest impact in terms of vibration and noise, the method still exceeds the 0.06mm/s minimum FTA requirement of a studio by a very wide margin (effectively an order of magnitude);

b) The junction under the MediaWorks building between the two tracks requires that at least part of the tunnel be developed with equipment other than a TBM. The most likely method is either an hydraulic hammer or a road header. Both methods induce higher and unacceptable levels of vibration and regenerated noise and persist for extended periods of time;

c) On the basis of the modelling completed for the current alignment, there are considered no construction methods that will comply with the requirements of low vibration that are necessary for an operating broadcast studio.

AMELIORATION OPTIONS WITHIN THE CURRENT BUILDING LOCATION

39. Few options are available to ameliorate the effects of tunnel generated vibration to the MediaWorks building given the stringent requirements necessary for a broadcast studio, the 24 hour per day operation and the large number of working areas within the building. Measures to reduce the effects on a building wide basis are not possible and at best, would be limited to one or two areas within the building.

40. It may be feasible to consider the possibility of isolating the broadcast studio from the tunnel construction generated vibration, and therefore regenerated noise, by constructing a new broadcast room within the existing studio. In the absence of detailed modelling to evaluate the magnitude of the isolation required, it is expected to necessitate considerable modifications which would at least include a new studio with a suspended floor anchored to the ceiling and therefore completed detached from the current concrete floor slab together with new walls that would need to detached from the current floor to ensure there is

no transmission of regenerated noise that occurs from though vibration in the walls.

41. I understand that implementing the above would be a significant construction task in itself and would take some time (eg: weeks) to install. That process would itself be incompatible with the continued operation of a studio as it would involve significant disruption to the current operations. Furthermore, the results of such works could not be guaranteed as acceptable, particularly given the very low noise level required. It would also reduce the operating space of the broadcast studio and limit the current use of the booms used with the lighting and audio.

REVIEW OF EVIDENCE

42. In preparing the following section, I have reviewed the Statements of Evidence prepared by:

a) Mr. William (Bill) Russell Newns

b) Mr. James Andrew Travis Whitlock

c) Mr. Matthew James Harrison

Newns' Evidence

43. Mr. Newns' evidence discusses the design constraints and indicative construction methodologies. In particular, the following paragraphs are considered important in assessing the impacts from the construction activities.

44. Paragraph 34 lists the key physical constraints considered as part of the reference design. There is no mention of the MediaWorks premises despite their location being immediately adjacent to the southern portal. This would infer that no particular attention has been considered in respect of the horizontal and vertical alignment of the tunnels, the location of the portals or the method of construction. Acknowledging the sensitivity of the MediaWorks building during the design stages would most likely to have resulted in the consideration of alternative alignments and construction methodologies.

45. Construction of the tunnel using a TBM is discussed in paragraphs 101 to 115 with particular reference to vibration effects in paragraphs 108 and 109. The duration of vibration from the boring of a single segment length is estimated between 40 minutes and 1 hour. It follows that vibration will occur continuously over a 40 to 60 minute period, followed by a short period of minimal vibration. The cycle repeats for approximately 20 hours per day, allowing for a typical four hour window for TBM maintenance.

46. Paragraph 109 also notes that for the purposes of developing a program, it is assumed that the time required to tunnel 100 metres with the TBM is up to two weeks.

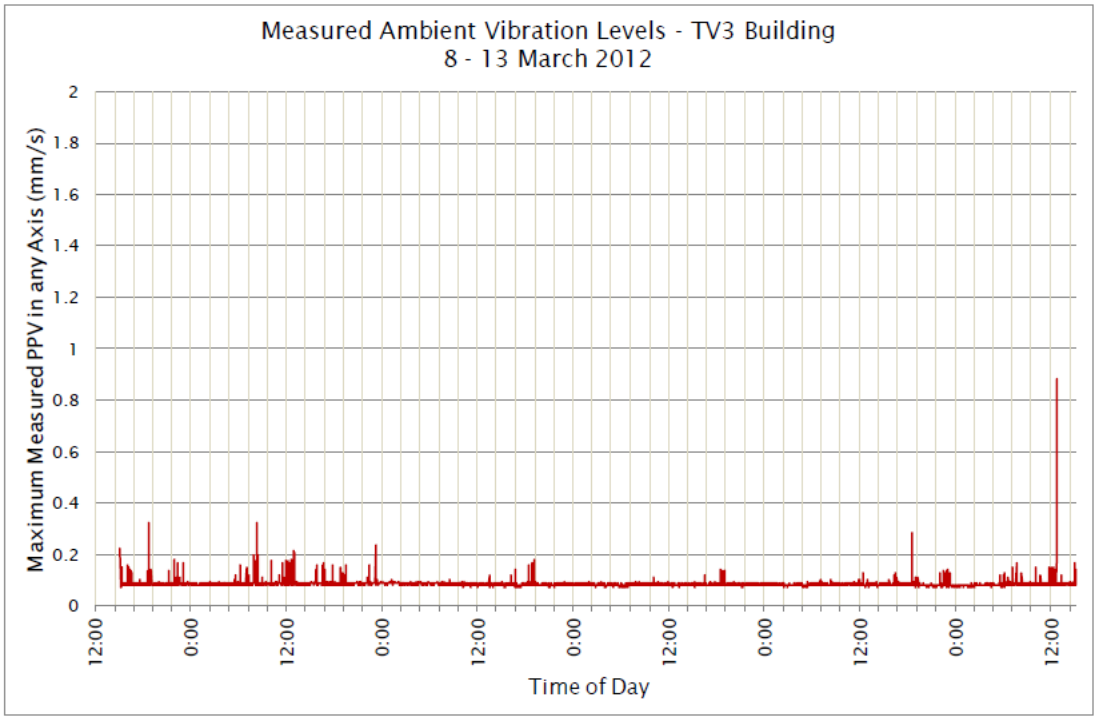
47. Paragraph 235 indicates that the portal immediately adjacent to the southern side of the TV3 studios will require excavation of a trench approximately 100 metres in length, 10 to 12 metres deep and 7 metres in width. It is proposed that blasting will be required to excavate this material. Paragraph 169 further indicates that in addition to the blasting, large hydraulic excavators up to 100 tonne will be required to remove the broken basalt.

48. Paragraph 237 also indicates that the turnout tunnels beneath the TV3 building are approximately 15 metres in diameter and will be excavated with road headers. The vibration is correctly considered “semi-continuous” by Mr. Newns. Whilst excavation rates for the TBM have been estimated by Mr. Newns as 100 metres in a two week period, no information is provided as to the productivity from a road header. My experience at other sites indicates that road headers are far less productive than a TBM with a production rate of 5 to10% of that of a TBM is comparable rock types a reasonable estimate, depending upon the tunnel dimensions. This would suggest that to complete the same 100 metre length of tunnel with a road header will take at least 10 times longer, or more than 20 weeks.

Whitlock Evidence

49. Mr. Whitlock's statement of evidence addresses the existing vibration environment, vibration performance standards and an assessment of vibration effects.

50. Paragraph 9 indicates that Mr. Whitlock has overseen the collection and analysis of data measurements to establish the existing vibration environment. On this basis of the measured data, the peak level of 0.9mm/s (ie: approximately 9 times the vibration level needed to induce regenerated noise) was considered representative of a level of vibration which the TV3 studio successfully operates under. Both Mr. Whitlock and Mr. Newns subsequently use this number as an acceptable vibration value in assessing the blasting, or at least an acceptable vibration value for the initial trial blasts. The monitor was positioned on the concrete floor of the TV3 main studio although within a room removed from the main studio open floor area. To assist in the further discussion, the vibration data collected and given in the MDA report and reproduced below:



51. A review of the MDA measured vibration data at the TV3 location indicates:

a) Over a five day period between the 8th and 13th March 2012, the measured vibration level exceeded 0.35mm/s on one single occasion with a peak level of 0.88mm/s. I do not consider that a single event of 0.88mm/s in a 5 day period is representative of the existing background vibration environment. Rather, it is clearly an exception to the norm.

b) In my opinion the minimum measured level of vibration of 0.09mm/s represents the lowermost level of vibration that can be recorded by the monitoring device rather than an actual level of vibration. In my experience inherent “electrical” noise within the electronics of the monitoring unit prohibits an accurate recording of lower levels of vibration. As a minimum analysis procedure, all measured vibration levels should be reduced by this amount of 0.09mm/s. Preferably, the data should be recorded again with a more accurate monitoring device.

c) I expect that the isolated peak of 0.88mm/s, and possibly most of the other elevated vibration peaks, relate to persons walking near the monitor or equipment being moved, probably between recording or broadcasting sessions (eg: prior to a particular programme or in breaks within the programme). In that case the peaks would bear little resemblance to the level of vibration occurring at the time of the studio broadcast. In my opinion, if vibration occurs outside the time of the broadcast then it is of little consequence.

d) My reading of the results is that the background level of the studio is no higher than the “baseline” of about 0.09mm/s (which for the reason discussed above is likely to be determined by measurement error and thus higher than the actual background). I consider it likely that the measured vibration peaks are very localised to the point where the monitor was positioned and are not representative of the vibration levels that occurred at other locations through the studio at the corresponding time. As an example, the monitor could be positioned near the stairs and record vibration levels from passing pedestrians in excess of 100mm/s however this does not suggest that the entire studio would receive this value.

e) The only relevance of the background monitoring is to determine if sources, such as traffic from outside, air conditioning vibration etc are of any significance. These measurements should be taken at the location near where the studio desk for the broadcast is located and the data assessed during the period when the broadcast studio is active. Further monitoring is being completed to confirm vibration levels in the studio at the time of a broadcast although I have not fully completed the analysis at the time of preparing my evidence.

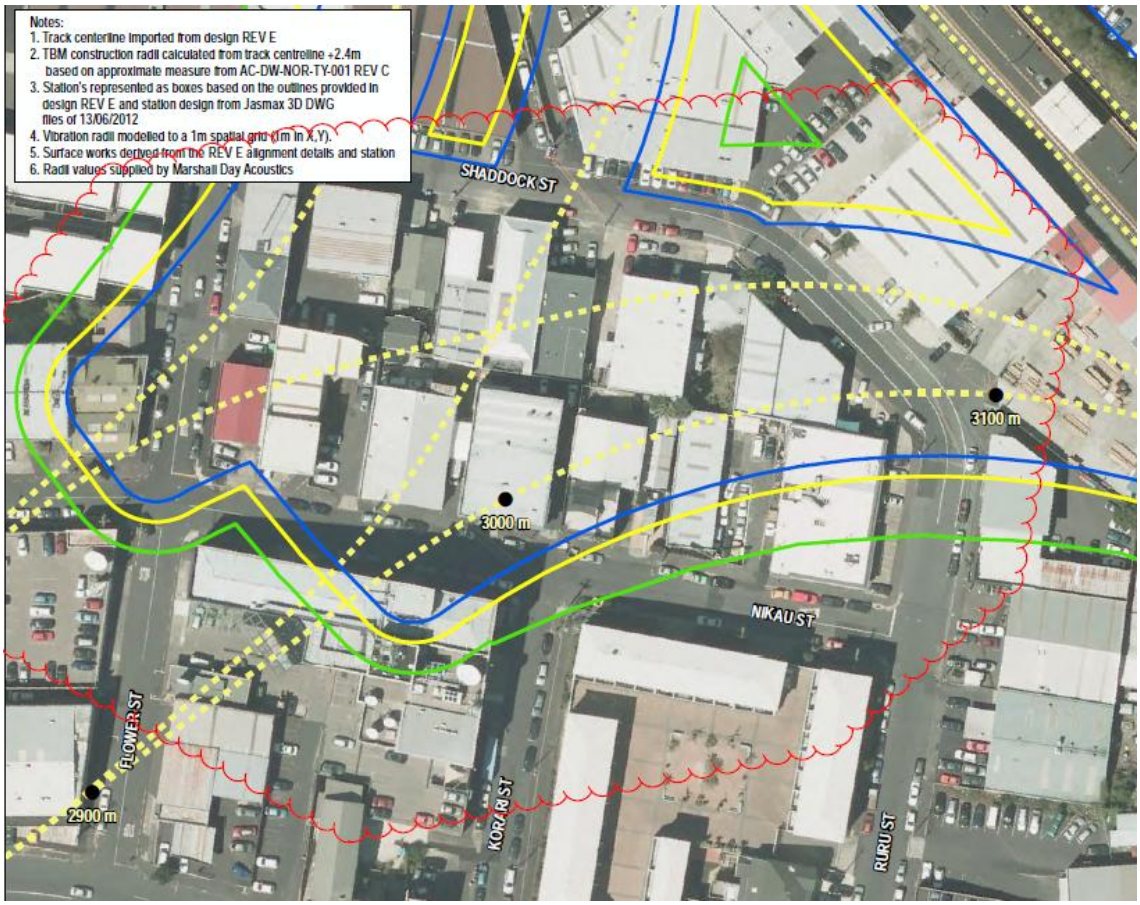
52. It is my opinion that the MDA measured vibration data in the TV3 studio are inappropriate and irrelevant to any comparison with continuous vibration that may, as indicated by Mr Newns, persist for up to 60 minutes (as would be produced by a TBM, road header or hydraulic hammer). Comments by Mr. Whitlock and Mr. Newns referring to an acceptable vibration level of 0.9mm/S in reliance on that data are flawed and incorrect. Further, the MDA report in Section 5.2.2 recognises that the peak level of vibration was not consistent with the rest of the monitoring period and the peak was therefore most likely due to a local activity, yet Mr. Whitlock and others continue to use the 0.9mm/s as an acceptable vibration value for subsequent assessment. The extract from Section 5.2.2 of the MDA report is shown below:

TV 3 Building	0.9	0.1	In general, the vibration environment at this site is low, with short periods of elevated vibration levels. The Max PPV event was not consistent with the rest of the period, so this was likely due to local activity in the studio area.

53. Paragraph 37 of Mr. Whitlock's evidence correctly suggests that a level of 0.06mm/s equates to a regenerated noise level of 25dBA. It is considered appropriate that the same 0.06mm/s criteria should apply to continuous vibration generated during the construction phase, particularly given that the construction vibration may persist for periods significantly longer than the 1 minute typical of the passage of a train. During tunnelling activities in the vicinity of the MediaWorks building, repeated periods of vibration throughout the day with each period of continuous vibration of up to 60 minutes are expected based upon the evidence of Mr. Newns. If the FTA criterion of 0.06mm/s for a vibration duration of 1 minute is appropriate, as proposed by both Mr. Whitlock and Mr. Harrison, a

permissible value not greater than this would be seen as equally relevant for longer duration vibration periods.

54. Mr. Whitlock has developed a series of construction contour maps showing where vibration criteria may be exceeded. These have been revised since the initial report, although it is unclear to me as why the revision was undertaken given the equipment used to develop the tunnel has not changed. The impact of the construction activities is referenced to the German Standard DIN4150 of 5mm/s which is appropriate for long term impulsive vibration, but inappropriate for continuous vibration. Impulsive vibration corresponds to vibration induced by activities such as blasting and occurs for a period generally not longer than a few seconds. Long term impulsive vibration corresponds to impulsive vibration that occurs many times during the construction period (ie, blasting every day over a six month period), although with each event only lasting for a few seconds. Continuous vibration differs from long term impulsive vibration in that the duration of an event is extended, with continuous vibration persisting often for tens of minutes rather than a few seconds. Whilst it may be appropriate to assess blasting induced impulsive vibration against the German DIN4150 Standard, it is inappropriate to assess those activities that produce continuous vibration, such as a TBM, hydraulic hammer, road header or other equipment indicated as being likely construction equipment by Mr. Newns, against the same German Standard. Mr. Whitlock has interchanged criteria appropriate for long term vibration versus continuous vibration on the basis of fatigue rather than amenity which is the commonly applied performance assessment parameter for continuous vibration. The contour map for the area about the TV3 studio is provided in Appendix H of the MDA technical report and is partially reproduced in the figure below:



55. I accept the method of showing vibration contours is a useful technique for identifying potentially affected properties, however I note in Mr. Whitlock's analyses that the level of vibration at the corner of the TV3 building where the studios are located is likely to exceed 1mm/s (ie: 10 times the level that produces regenerated noise) with more than 2/3 of the building receiving vibration above 2.5mm/s (green contour) (ie: 25 times the level that produces regenerated noise). It is also unclear as to why the vibration contours are of the shape shown in the drawing shown in the MDA report. I would have expected that the contours would continue about the alignment of the tunnel rather than cease at allocation through the MediaWorks building. I am also unsure as to the source of the vibration and whether this vibration relates to a TBM or other method of construction, particularly given the ambiguity about the method of construction. Equally important, the predicted levels of vibration do not take into account the construction of the MediaWorks building which is detailed in the evidence of Mr. Simpson and Mr. Vaughan. The piered construction method is likely to affect the accuracy of the vibration prediction, particularly given that the piles on which the

building in the area of the broadcast studio are founded extend deeper into the material between the building and the tunnel, effectively reducing the length of the transmission path for the vibration between the building and very likely increasing the level of vibration receiving from any tunnelling activities.

56. It is my opinion that as well as assessing whether the construction activities could impact upon building integrity, additional analyses and possibly a similar set of vibration contours should have been generated to show the location of lower levels of vibration that would be aligned with performance criteria for personal amenity or special building environments.

57. I concur with Mr. Whitlock that the likelihood of vibration damage to the TV3 studio buildings from construction activities that comply with the proposed German Standard DIN4150 is extremely low. I therefore agree with Mr. Whitlock that the contour analyses presented in Appendix H are appropriate to assess the likelihood of building related damage, however there are no analyses presented in the report comparing the predicted magnitude of the construction generated vibration with limits based around amenity, or those necessary to maintain an environment required for a broadcast studio. My comments regarding the accuracy of these predictive contours as discussed in paragraph 55 of my evidence are still considered relevant.

58. It is known that the levels of vibration at which superficial damage, such as flaking of paint or cracking of plaster occurs, is well below the threshold of human perception for vibration. Mr. Whitlock correctly notes the limit of perception as around 0.3mm/s which is significantly less than the proposed 5mm/s vibration limit to ensure the building fabric is preserved. In Paragraph 12, Mr. Whitlock indicates that his analyses address both the risks of building damage and occupant annoyance. In my opinion, Mr. Whitlock provides an acceptable review of the likelihood of building damage but fails to address issues relating to amenity, equipment protection or maintaining an environment appropriate for special building uses, such as a broadcast studio. The assessment of Mr. Whitlock is limited to “I anticipate that these effects can be appropriately managed through a Construction Environmental Management Plan”.

59. I accept that the approach of education and management is a responsible approach and can normally be successfully implemented where construction activities occur adjacent to residential properties. The owners can be informed of the likely vibration and any fears concerning vibration related building damage addressed, instructed about the likely time frame of activities and in the extreme, relocated where necessary. This same approach has been well implemented for other large tunnelling projects completed throughout the world. The "educate or relocate" approach ensures amenity for persons about the construction site is generally protected.

60. It is however inappropriate as a control measure where the receiver, in this case TV3 MediaWorks, requires a quiet and vibration/noise free environment to conduct their business. Additional assessments are required and should be documented to show amongst other information, the expected level of vibration, the duration of this vibration as well as the times at which it is likely to occur. This information has not been provided in the documents that have been supplied to me.

61. The assessment prepared by Mr. Whitlock is therefore considered inadequate in that there are no performance criteria relating an acceptable level of "occupant annoyance" or special building environment use.

62. Whilst paragraph 192 of Mr. Whitlock's evidence suggests some very limited content for a Construction Environment Management Plan (CEMP), it provides nil to minimal information that would allow MediaWorks to determine how the vibration will be managed. I have no confidence that the construction activities can co-exist with the day to day operation of the TV3 studio.

Impacts on Sensitive Equipment

63. None of the statements of evidence that I have reviewed assess, or make any comment regarding, the possible impacts of the construction vibration on sensitive electronic equipment that is housed within the TV3 studios.

64. It is known that electronic equipment manufacturer's specifications provide information on permissible vibration and acceleration values that are shown to have no effect on the ability of the equipment to operate continuously. My preliminary analyses show that, based upon the equipment specifications that I have been provided with, a further review of the effects is required.

65. The evidence of Mr. Randle lists published vibration limits of core technologies by device type that are used in the MediaWorks building. Whilst the list is not exhaustive, it contains manufacturers' specifications for acceptable vibration values for hard disk drives, fibre switches, bus adaptors, and servers. The specifications indicate acceptable values for operating modes with the minimal value for the listed equipment as 200mg in the frequency band 5 to 500Hz. When compared with the blasting vibration criteria listed in the German Standard DIN4150, the permissible equipment specifications are acceptable at the 5mm/s limit although likely to be exceeded by the 10mm/s value proposed in the MDA report as appropriate for the MediaWorks building.

66. I suggest that further analyses are required to give confidence that the proposed standards will not damage the equipment in the MediaWorks facility.

Blasting

67. Both Mr. Whitlock and Mr. Newns propose that any blasting would be prefaced by a detailed trial blasting study to assess the likely range of explosive quantities that could be used. I agree that this approach follows best practices and is strongly encouraged.

68. Whilst I concur that the blasting trials should comply with an appropriate vibration limit at the TV3 studios, I do not agree with the suggested value of 0.9mm/s on the basis that this reflects an existing "safe" vibration environment. My reasons for this have been discussed in previous paragraphs of my evidence.

69. Rather, I suggest that the appropriate vibration limit is one which considers the potentially sensitive equipment within the building and determines a vibration value according to the electronic manufacturer's recommendations. Not

surprisingly, a survey of the TV3 studios shows a vast suite of electronic equipment that could be vulnerable to increased levels of vibration. The appropriate value may be higher or lower than the 0.9mm/s value, however it will be justifiable and based upon engineered information.

70. Any blasting that does take place will need to occur at a time acceptable to MediaWorks in terms of its recording and broadcasting activities.

Harrison Evidence

71. I have read through the statement of evidence by Mr. Harrison and note that it primarily addresses noise related issues and will therefore be discussed in greater detail by Mr. Simpson. I have however noted the following items of significance with respect to vibration impacts.

72. I note that Mr. Harrison in Paragraph 36 of his evidence presents vibration envelopes showing the expected duration of any impact. The information presented is based around an advance rate for the TBM of 20 metres per day which differs from the information presented by Mr. Newns which indicates an advance of 100 metres in a two week period. Whilst I accept Mr. Harrison's value of 20 metres per day is achievable once the TBM has progressed a reasonable distance into the tunnel and operating procedures are streamlined, Mr. Newns' number is far more credible for an assessment at the start of the tunnel and therefore applicable to the effects on the TV3 studio if a TBM is used at all in that part of the tunnel. In my opinion the graphs of effects duration presented in Paragraph 36 of the statement by Mr. Harrison are therefore overly optimistic and not representative of what vibration at TV3 could be expected. As I have explained above, even if a TBM is used in the vicinity of the MediaWorks site I consider that other techniques will also be needed to construct the broader tunnels proposed.

73. Like the evidence presented by Mr. Whitlock, Mr. Harrison's statement also focuses on vibration criteria pertinent to the prevention of building related damage but with no regard for the protection of electronic equipment, including sound audio and visual equipment that would be utilised in the sound studios.

The evidence also has little emphasis on vibration related “occupant annoyance”. It is accepted that the likelihood of building damage is minimal however there is no supporting information to indicate that the effects on persons within TV3 studio building or the equipment housed in the building will be unaffected and therefore confirmation that MediaWorks can continue to operate unimpeded.

74. Paragraph 41 of Mr. Harrison’s evidence indicates a trial blast could be completed using a 1 kilogram explosive weight which is predicted to produce 5mm/s at a distance of 20 metres. To illustrate the variability that can exist with vibration from blasting, blasting activities with a 1.5 kilogram explosive quantity at the Waterview project, which is in a similar rock mass, produced 15.8mm/s at a distance of 20 metres. In my opinion, the proposed vibration relationship is possibly optimistic (ie may underestimate the level of vibration for a given explosive quantity) and may lead to lower explosive quantities which would increase the requirement for the use of large scale hydraulic hammering equipment to facilitate breakage as documented by Mr. Newns in his evidence.

75. I note that both Mr. Whitlock and Mr. Harrison are in agreement that that the FTA criteria are appropriate to determine if the potential for vibration related impacts exist. In particular, the acceptable vibration level to comply with the proposed 25dBA criterion for the studios is 0.06 mm/s. I believe it is reasonable to conclude that if this criterion is appropriate as proposed by Mr. Whitlock and later confirmed by Mr. Harrison in his evidence, for assessing the vibration from train movements, which could persist for up to one minute whilst the train passes beneath the building, a value no greater than 0.06mm/s would also be appropriate for assessing potential impacts from construction activities that generate vibration for much longer periods (eg: as indicated by Mr. Newns as possibly 40 minutes to 1 hour in duration). It would therefore follow that vibration above 0.06mm/s would be in conflict of the FTA criteria, non-compliant with the proposed performance standard and inconsistent with the vibration environment requirement for a broadcast studio.

76. I note that the FTA performance standard relates to operational vibration and not construction activities, however I consider it an oversight of the assessment document that a performance criteria for personal amenity is not provided and

the only recourse of evaluation for such vibration is a range of mitigation measures proposed to be documented in a Management Plan.

77. I believe that it is reasonable to conclude that, based upon the modelling provided Mr. Whitlock and presented in Appendix H of the MDA, that the level of vibration will most certainly exceed this FTA criteria and would therefore be considered to impact upon the ability of MediaWorks to operate a broadcast studio.

78. I note that in Paragraph 40 of the evidence prepared by Mr. Harrison that the highest vibration impact is predicted to be from a vibratory roller associated with the cut and cover tunnelling. The paragraph further indicates that similar activities occur all over the city from normal road upgrade works. I dispute that a vibratory roller will generate the highest level of vibration when Mr. Newns has indicated in Paragraph 167 of his evidence that hydraulic breakers up to 100 tonne will be required to remove the competent basalt rock. My experience and a review of measured data show that a large hydraulic breaker of the size indicated by Mr. Newns will generate vibration more than three times that generated by a vibratory roller operating at maximum vibration mode when measured at the same distance.

CONCLUSIONS

79. It is my professional opinion that the construction of the tunnel based upon the current alignment and method of construction cannot coexist with the restrictive vibration and noise requirements necessary of a broadcast studio.

80. The MDA documents are void of proposing any vibration criteria applicable to personal amenity, or that which ensures the continued operation of potentially sensitive equipment within the TV3 studios during construction. Instead they rely upon these effects being managed through a yet to be documented Environmental Management Plan. In that context, and given the sensitivity of the MediaWorks site and the duration of the construction phase, I consider it appropriate to extend and apply to the construction phase the 0.06mm/s vibration criterion documented in the FTA criteria for TV/Recording studios that were

proposed and considered appropriate by Mr. Whitlock for operationally induced vibration.

81. A comparison with this FTA vibration criterion, and the construction methods presented by Mr. Newns as requiring the use of TBM, road headers, and large hydraulic breakers, indicates that compliance with this level cannot be achieved. A severe impact on the TV3 studio is therefore expected, preventing MediaWorks from continuing to operate under its current flexible recording and programming schedule during the construction phase.

82. It is agreed that blasting could induce higher levels of vibration than the FTA criteria as a consequence of the impulsive nature of this vibration and its short duration. The permissible criteria of 5mm/s is protective of building fabric, however further studies should be completed to ensure that there is no detrimental effect on the sensitive equipment within the building, including the ability to operate sound and camera recording equipment

83. It is therefore my recommendation that, as a minimum, appropriate vibration and regenerated noise criteria consistent with requirements of an operating broadcast studio are applied by way of condition to administer the construction activities for the project. It is reasonable to conclude that that the proposed FTA criteria are applicable in this regard.

84. These impacts of the works should be analysed and should the proposed construction methods not be able to comply with these values, from a practical perspective I suggest other tunnel alignments, including the relocation of the portal, should be evaluated. These alignments would reduce or possibly eliminate the extent of tunnelling, including both TBM and the road header, beneath the TV3 building. Finally, should these options be unsuitable, options to relocate the broadcast studio should be considered.

John Heilig; 26 July 2013